



A New Energy Future for Montana, Idaho, South Dakota, Wyoming, the Pacific Northwest and the Nation

2006
REGIONAL CARBON SEQUESTRATION
PARTNERSHIPS ANNUAL REVIEW MEETING
National Energy Technology Laboratory
Pittsburgh, PA
October 3-4, 2006

Susan Capalbo, Director
Montana State University
Big Sky Carbon Sequestration Partnership
www.bigskyco2.org

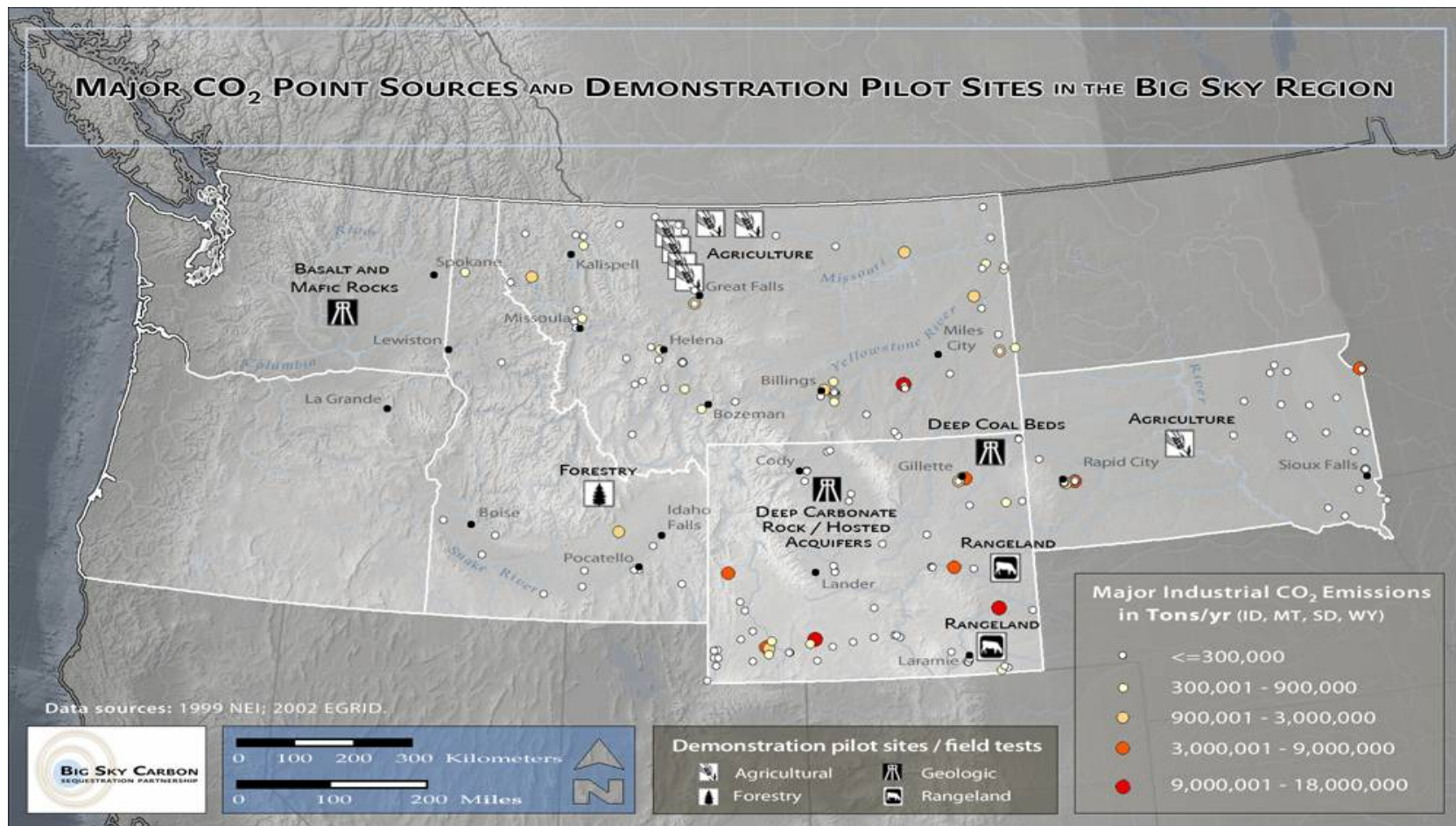
Outline of presentation

- **Overview of the Big Sky partnership efforts**
- Sources and sinks in the region
- Promising Geological sequestration opportunities
- What will it cost??

Overview

- Partnership Goal: **Develop infrastructure to support and enable future carbon sequestration field tests and deployment(regional orientation)**
- Phase I: 2003-2005 scoping/screening effort
- Phase II: Two focal areas: **geological** and **terrestrial** sequestration opportunities

MAJOR CO₂ POINT SOURCES AND DEMONSTRATION PILOT SITES IN THE BIG SKY REGION



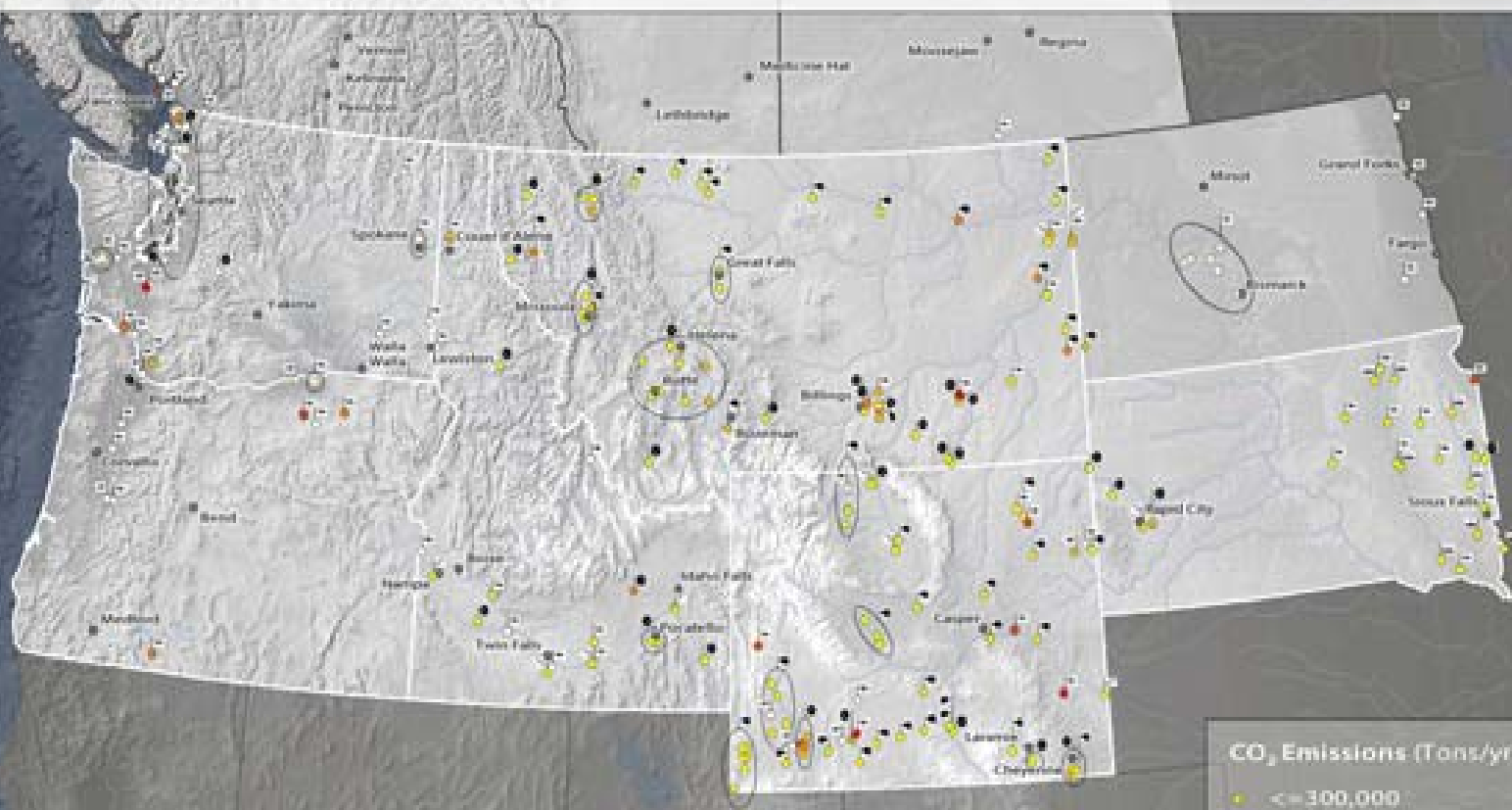
Outline of Presentation

- Overview of the Big Sky partnership efforts
- **Sources and sinks in the region**
- Promising Geological sequestration opportunities
- Other sequestration questions

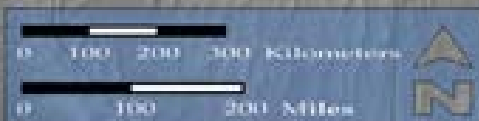
Sources and Sinks

- GIS Component
 - Sources and Sinks Identification and Characterization
 - Carbon Atlas
 - National Mafic Rock Atlas
 - Site Specific Characterizations
 - Base Data/Infrastructure
 - Terrestrial and Economic Data Layers

THE BIG SKY REGION: MAJOR INDUSTRIAL POINT SOURCES OF CO₂



Data sources: 2006 Pennwell Corp.[†], 1999 EGRID, 1996 NEI.



- ▣ Power Generation Plant
- ▣ Petroleum and Natural Gas
- ▣ Ethanol
- ▣ Agricultural Processing
- ▣ Industrial

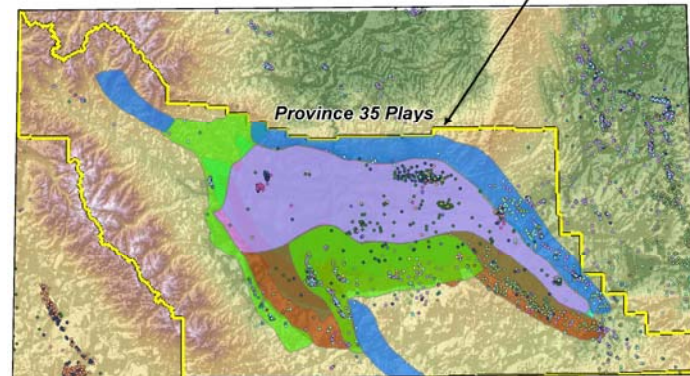
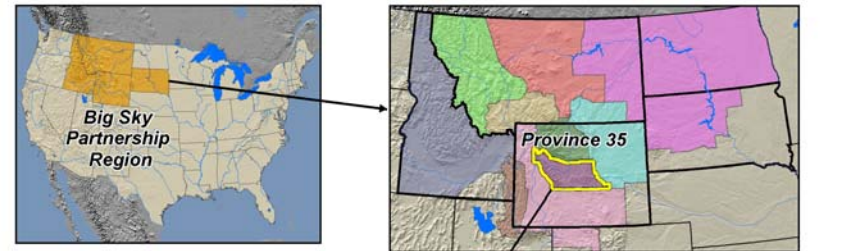
CO₂ Emissions (Tons/yr)

- ≤ 300,000
- 300,001 - 900,000
- 900,001 - 3,000,000
- 3,000,001 - 9,000,000
- 9,000,001 - 18,000,000

† Emissions Data Unavailable

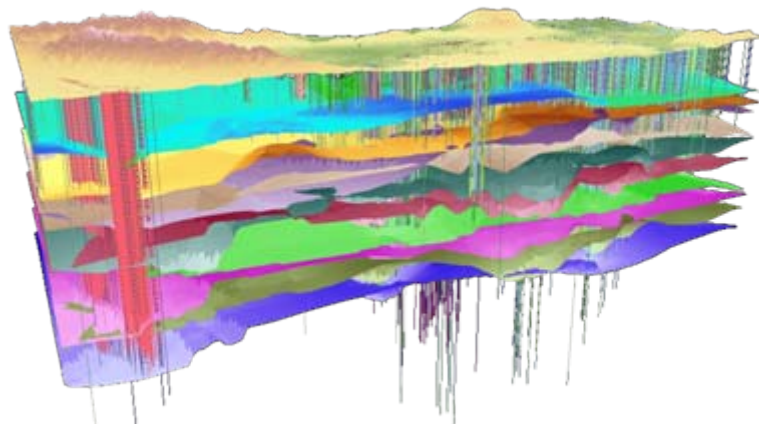
Building the Geological Carbon Atlas

- Compiled data from 117,304 active wells in WY and MT
- Developed GIS model to calculate sequestration volumes (based on depth, temperature, pressure, density, and thickness)
- Characterized sequestration volumes for 283 formations in 57 plays

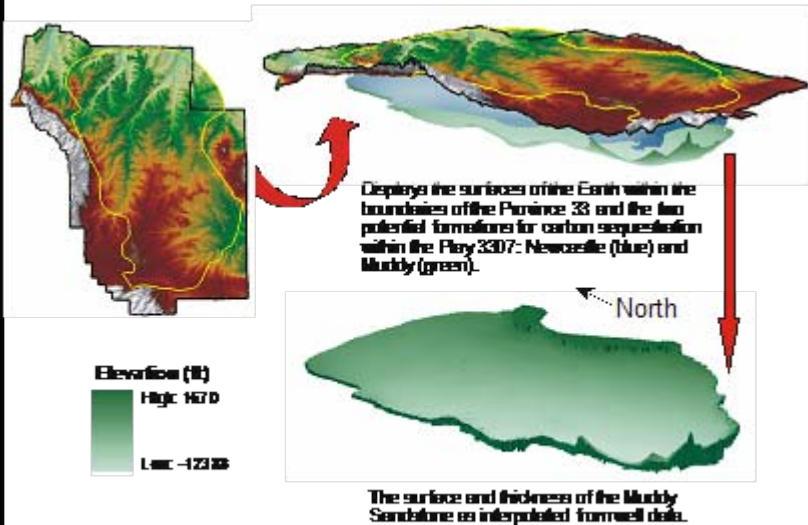


Wells by Formation

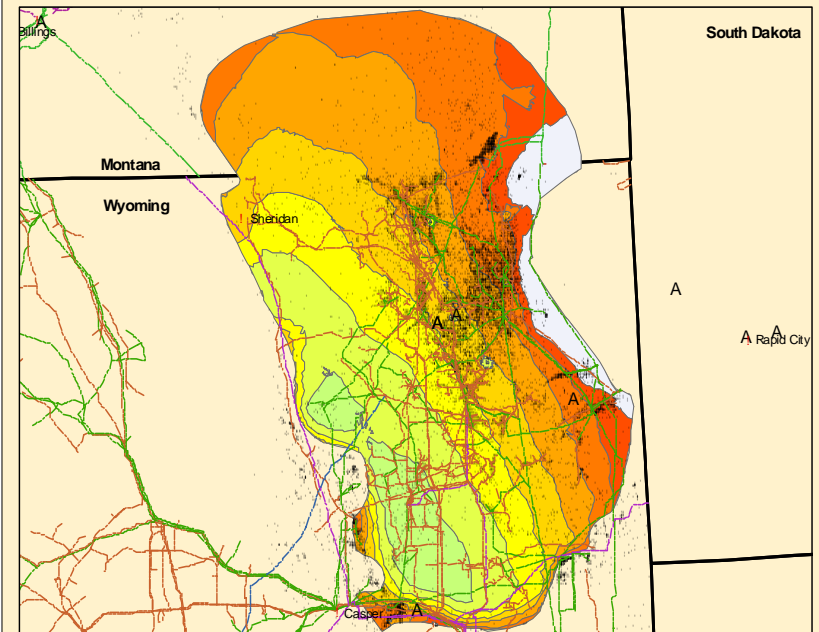
- * CLOVERLY
- * CODY
- * CROW MOUNTAIN
- * DAKOTA
- * FORT UNION
- * FRONTER
- * JELM
- * LAKOTA
- * LANCE
- * MADISON
- * MEETEETSE
- * MESAVERDE
- * MORRISON
- * MUDDY
- * NUGGET
- * PHOSPHORIA
- * SUNDANCE
- * TENSLEEP
- * WIND RIVER



Developed maps of each formation within all plays



Muddy Sandstone 3307



Note: All depths and sequestration volumes are based on wells within Wyoming and Montana only.

0 15 30 60 90 120 Miles

Legend

A Coal Plants

! Cities

Pipelines

Carbon Dioxide

Crude Oil

Natural Gas

Processing Product

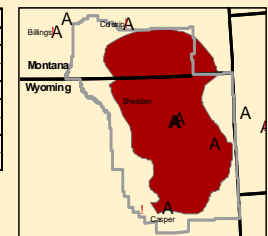
Wells

(points displayed with 1/2 mile diameter)

Province

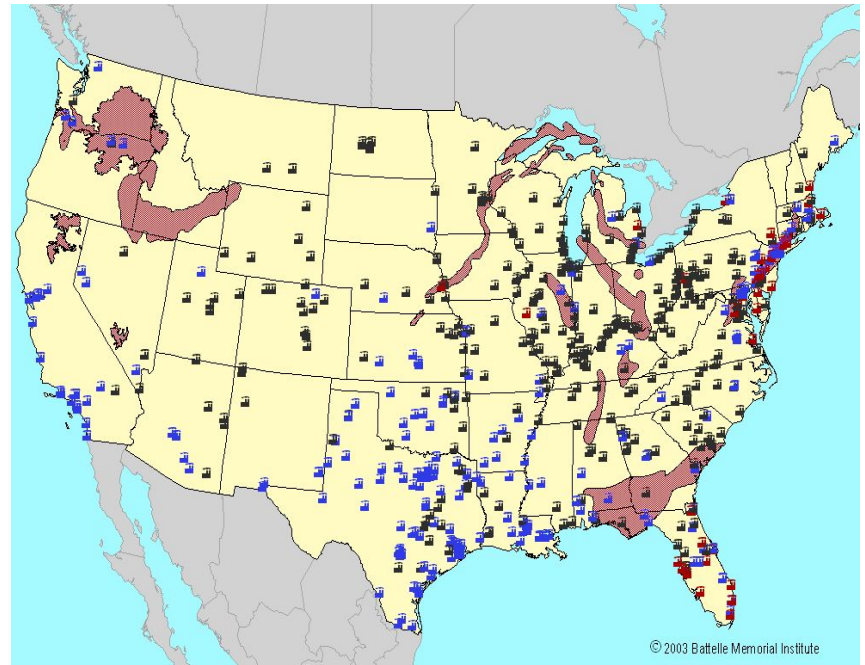
State boundary

| Depth (m) | Cost (\$) | Volume (MMT) |
|-------------|-----------|--------------|
| 0 - 800 | | 0.00 |
| 800 - 1300 | 251,234 | 133.37 |
| 1300 - 1800 | 374,798 | 510.10 |
| 1800 - 2300 | 559,133 | 681.98 |
| 2300 - 2800 | 834,128 | 393.17 |
| 2800 - 3300 | 1,244,372 | 339.51 |
| 3300 - 3800 | 1,856,386 | 262.73 |
| 3800 - 4300 | 2,769,402 | 105.40 |



National Mafic Rock Atlas

- Develop a GIS-based tool that integrates
 - modeling studies
 - laboratory tests
 - pilot project insights
- Provides for transferability of pilot results nationally and internationally

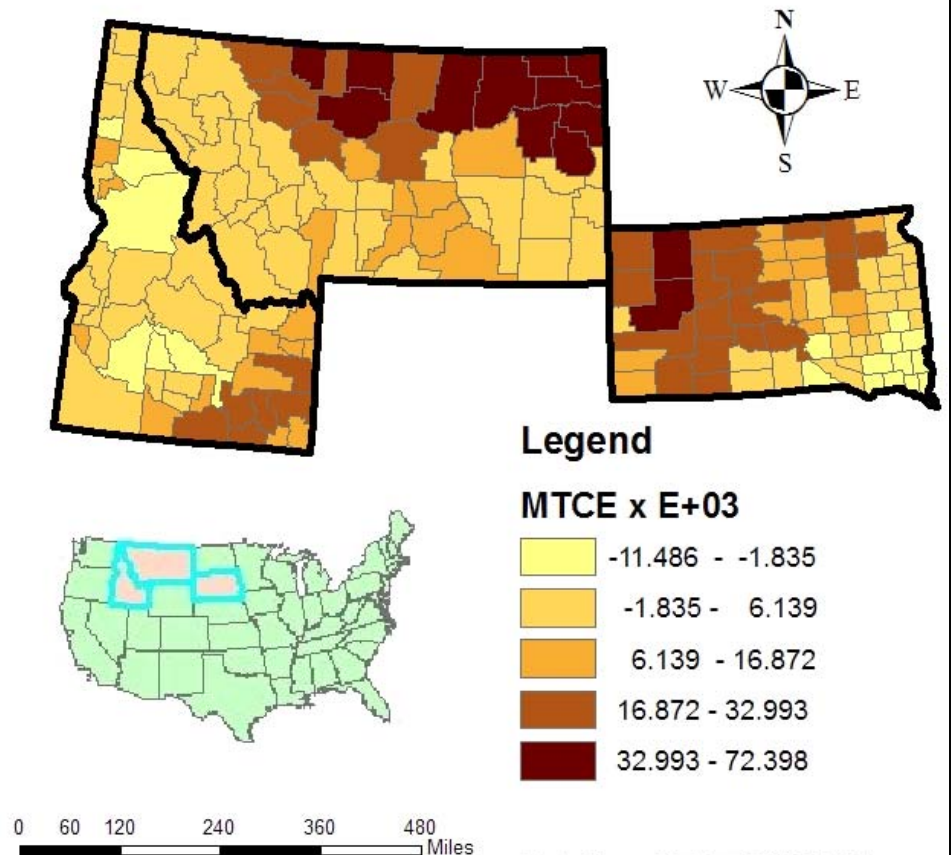


Many power plants are located near large basalt provinces

- Exist in regions with limited “conventional” capacity
- Prevalent in regions with large future electrical generation growth

Building the Terrestrial Carbon Atlas

- Used Century Model to examine terrestrial carbon flux (based on climate, soil, land use)
- Evaluated management scenarios for continuous grassland and conventionally-tilled cropland
- Estimated current annual soil carbon fluxes in Big Sky states



Data from CENTURY Model run
(MTCE=Metric Tons C Equivalent)
Map by SDSM&T

Outline of presentation

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- Sources and sinks in the region
- **Promising Geological sequestration opportunities**
- Other sequestration issues

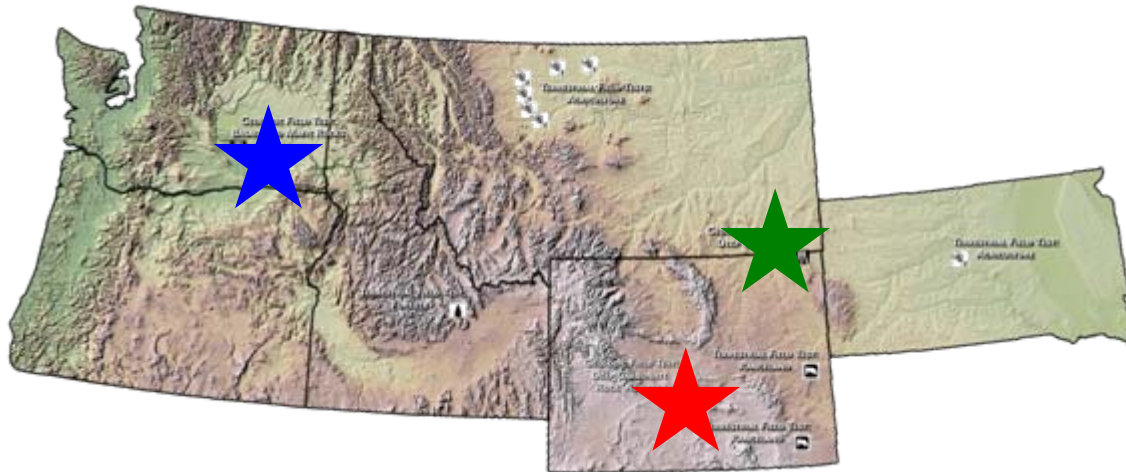
Geological Sequestration Efforts – Phase II

Demonstration projects

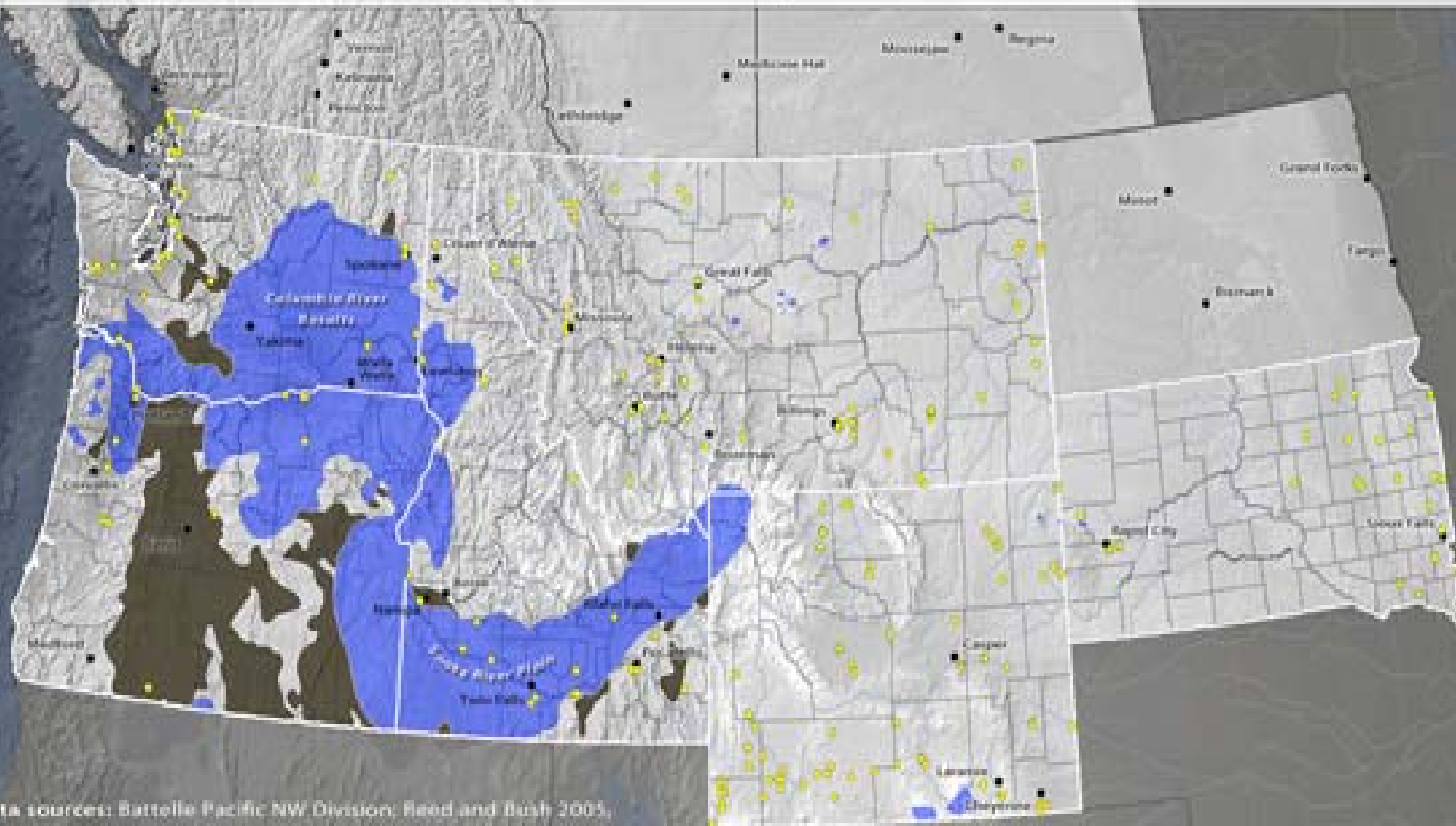
- basalt/mafic pilot scale injection (form solid phase carbonates)**
 - carbonate aquifer assessment (develop carbonate alkalinity)**
 - deep coal bed exchange (separate and sequester from flue gasses)**
-
- Transfer results to the Nation**
 - national mafic/basalt atlas**

Geologic Field Activities

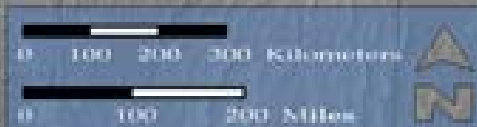
- **Basalt and Mafic Rock Field Validation Test**
 - National Mafic Rock Atlas
- **Reactive Carbonate Reservoir (Madison Formation) Field Validation Test**
- **Enhanced Coal Bed Methane Recovery and CO₂ Sequestration**



THE BIG SKY REGION: POTENTIAL CO₂ SINKS - MAJOR FLOOD BASALTS



Data sources: Battelle Pacific NW Division; Reed and Bush 2003, <http://pubs.usgs.gov/atlas/geologic/>; 2006 Pennwell Corp.; 1999 NEI; 2002 EGRID.

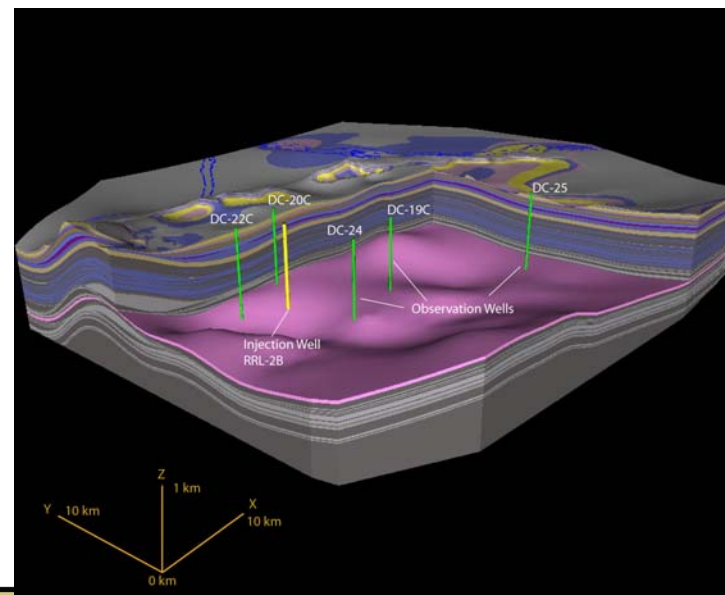
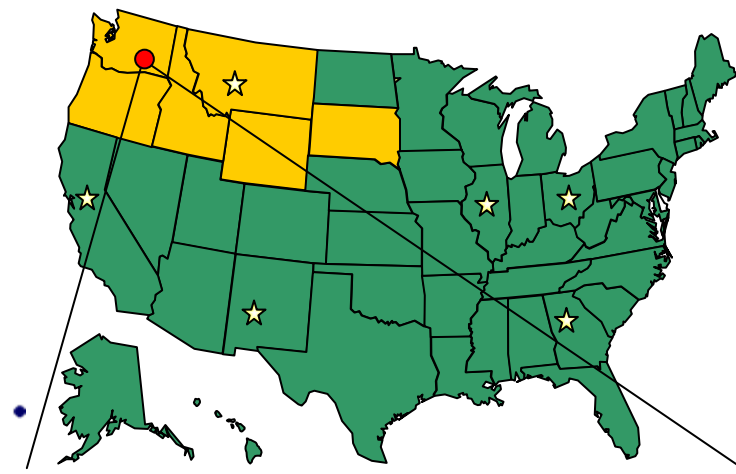


Major Industrial CO₂ Source

Basaltic formations
Other volcanic rocks

Basalt and Mafic Rock Field Validation Test

- 3000 MT of CO₂ transported by rail from refinery
- Utilize existing deep well infrastructure to minimize drilling costs for injection and monitoring
- Target is Grande Ronde basalt formation (1,100 m depth)
- Post injection core sampling to verify mineralization reactions
- NEPA CX application prepared for submission
- Pre-injection work with existing well to begin Dec 06
- MMV plan complete in Oct 06

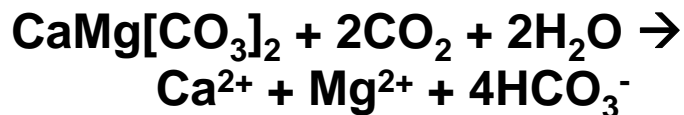


Conclusions: Sequestration in Basalts

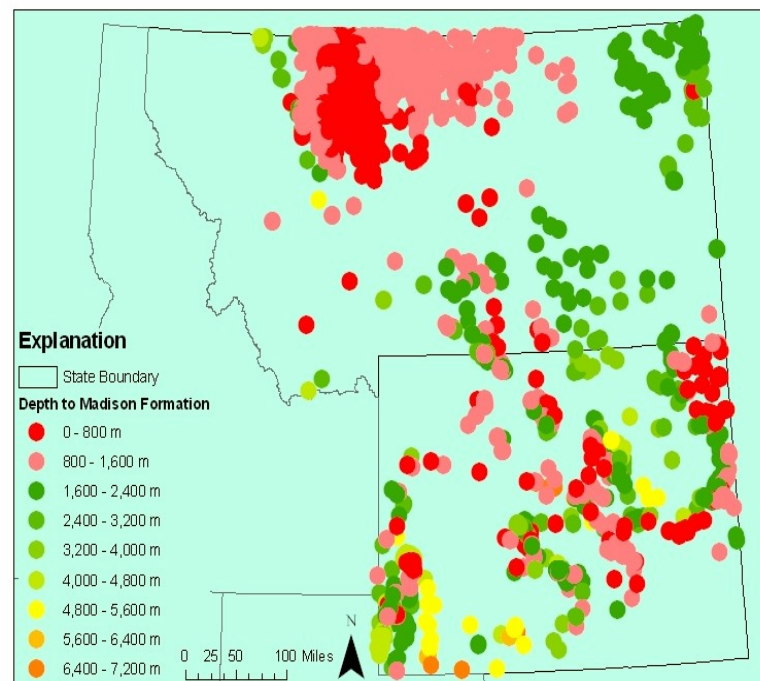
- **Large basalts provinces globally distributed**
- **Economic opportunity costs of using basalts are minimal**
- **Conducive mineralogy for sequestration**
- **Rapid conversion of CO₂ to carbonate**
- **High porosity and permeability**
- **Five largest basalt provinces could sequester 10,000 years of world CO₂ emissions**
- **Big question: how does this compare to costs of other sequestration and mitigation options**

Pilot Demonstration: Carbonate Petroleum Reservoir

- Regionally abundant carbonate rocks (dolomites and limestones) are highly reactive with CO₂

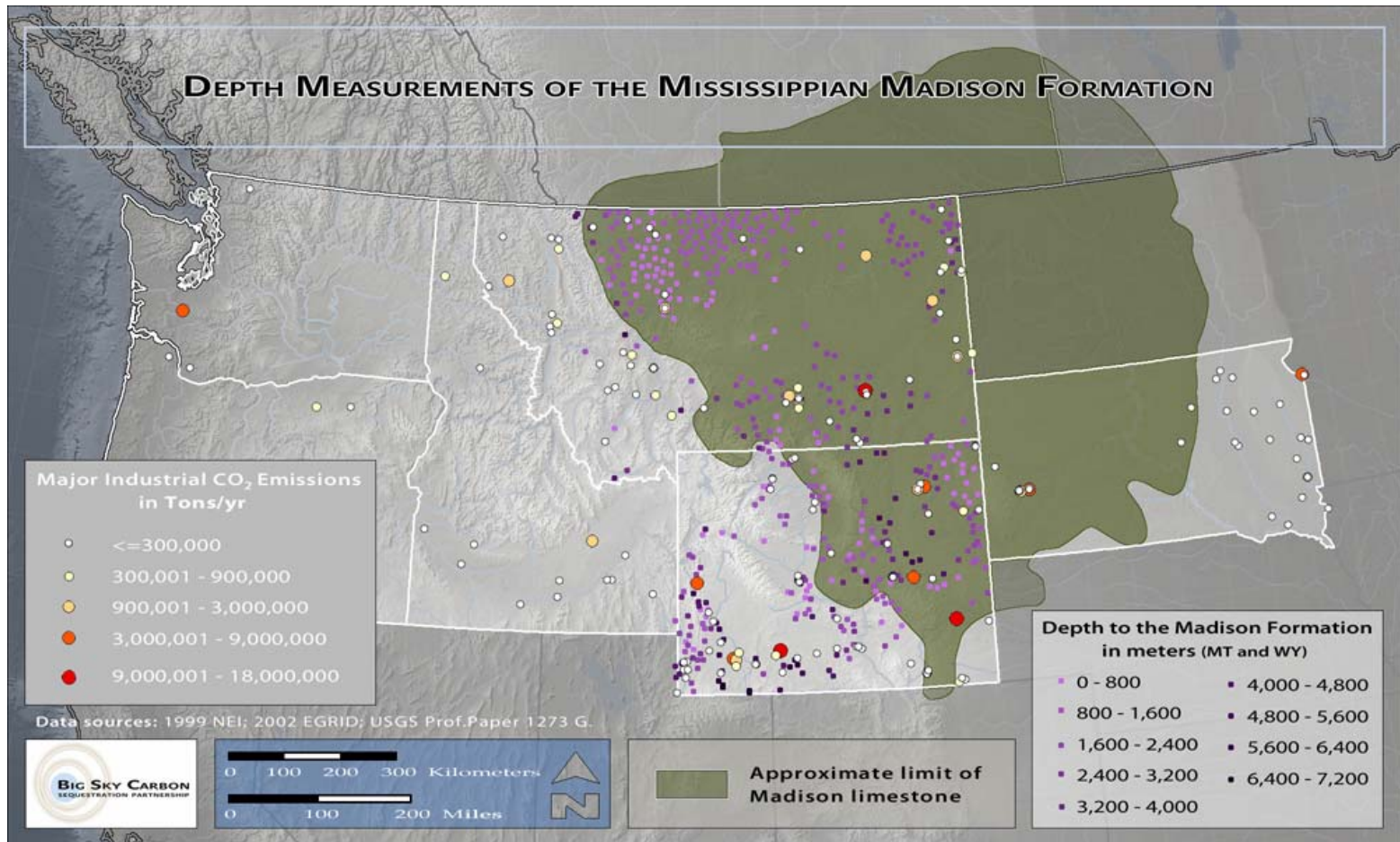


- Reactions should result in permeability and porosity increases



Depth to Top of Madison Formation

BIG SKY PARTNERSHIP: Matching Sources and Carbonate Petroleum Reservoirs: Madison Formation

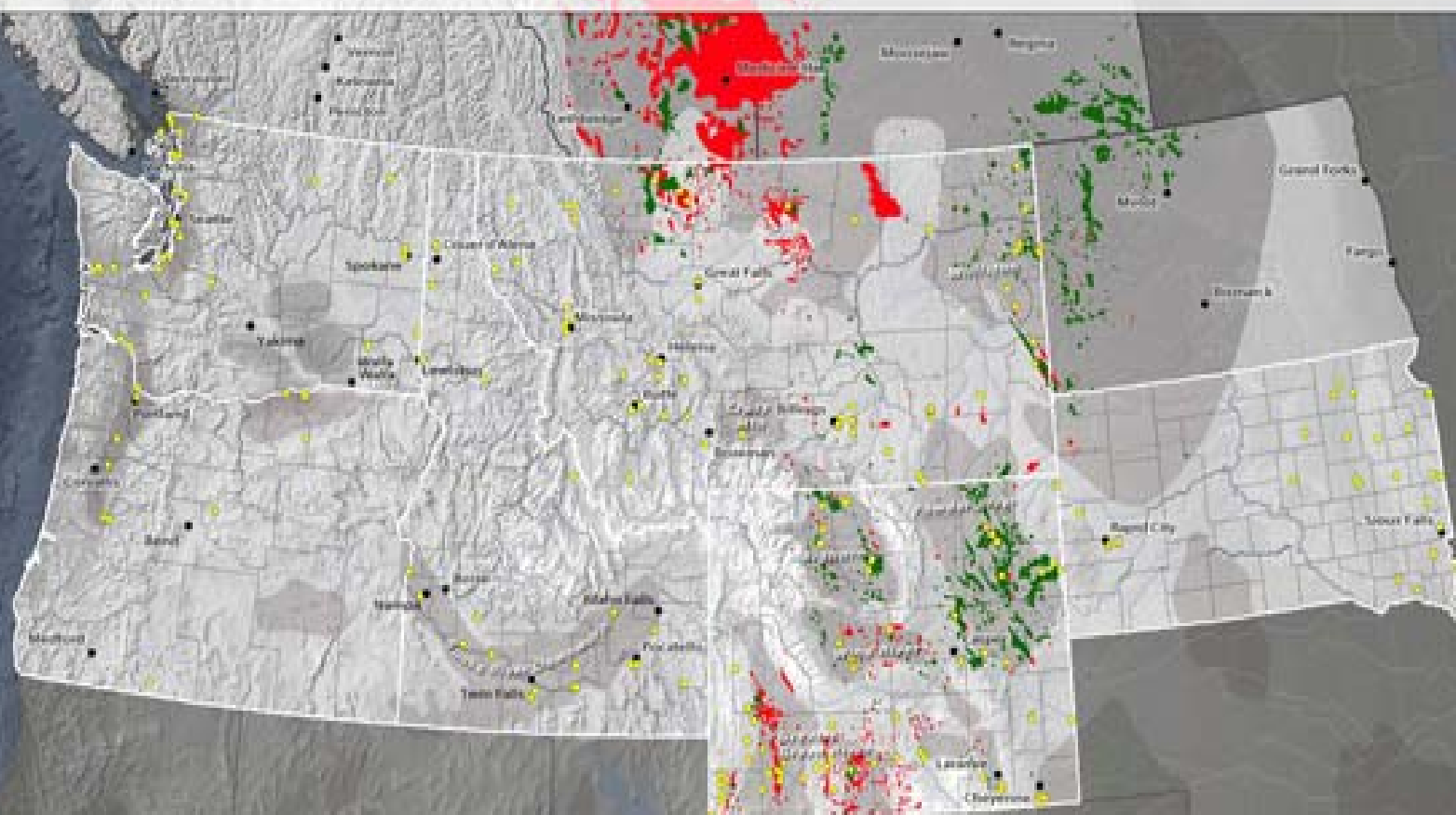


Objective and Approach

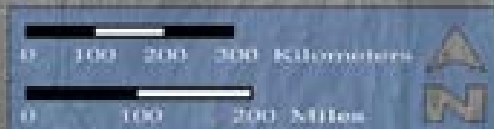
- Assess long-term CO₂ mineralization rates in a carbonate hosted reservoir (Madison Formation)
- Collect core from reservoir that has undergone CO₂ EOR
 - long CO₂ exposure history
 - Compare to pre-injection core
 - Validate predictive modeling of CO₂ injection

- Update: EOR opportunities in the Region
 - High oil/gas prices make EOR attractive
 - Sources of CO₂? IGCC?
 - Existing sources are natural (LaBarge Cr Plant)
 - Infrastructure to deliver CO₂ from existing and future point sources (\$900k/mi pipeline cost)
- Enhanced Coal Bed Methane
 - Flue gas injection vs. pure stream

THE BIG SKY REGION: POTENTIAL CO₂ SINKS - OIL AND GAS FIELDS



Data sources: 1991 The Geological Society of America, Inc.;
2006 Pennwell Corp.; 1999 NEI; 2002 EGRID.

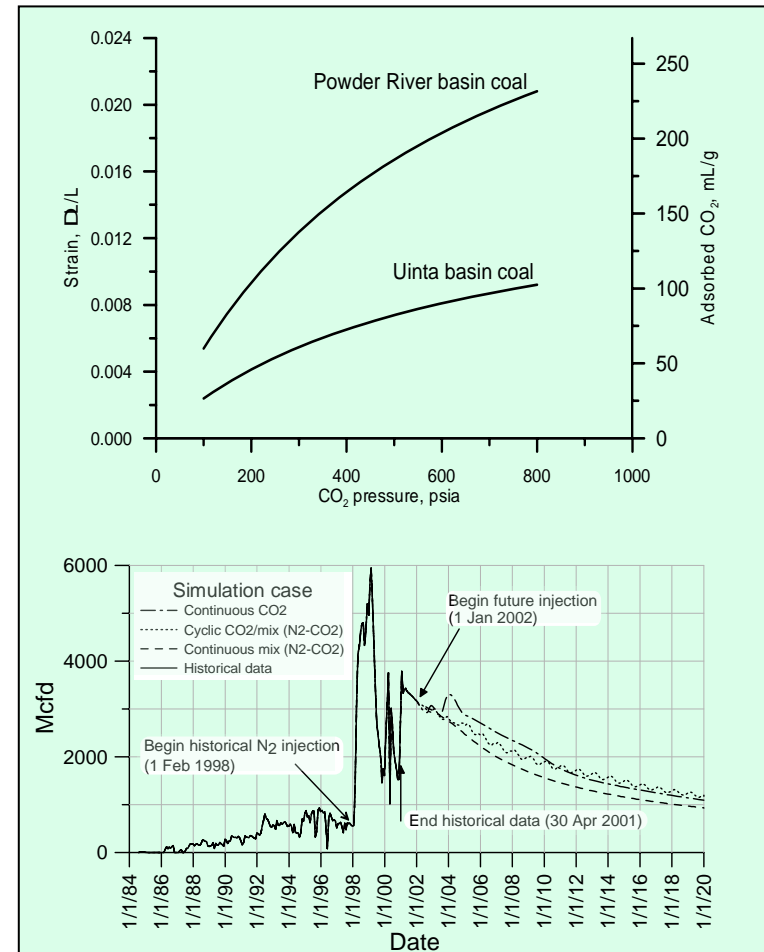


Major Industrial CO₂ Source



Pilot Design: Enhanced Coal Bed Sequestration

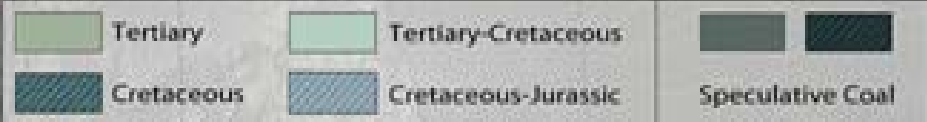
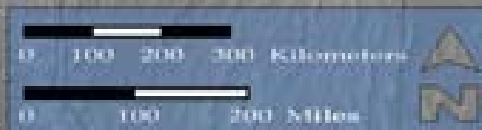
- Recent work shows Powder River basin coals can adsorb twice as much CO_2 as Uinta basin coals
- Study various gas injection strategies
 - Economic evaluation
 - Reservoir simulation
- Attention will be given to impact of coal swelling on permeability changes
- Submission of the Detailed reactive carbonate reservoir project plan



THE BIG SKY REGION: POTENTIAL CO₂ SINKS - COAL FIELDS (U.S.)



Data sources: 1991 The Geological Society of America, Inc.



Outline of Presentation

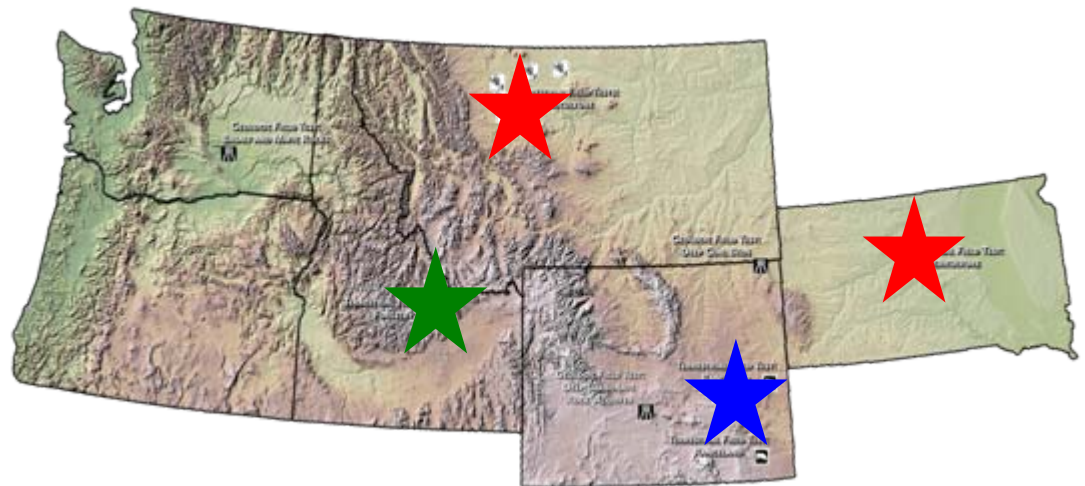
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- **Other sequestration issues**

Terrestrial Sequestration Efforts

- **Market-based storage and verification protocols**
- **Terrestrial Pilots and Activities:**
 - **cropland**
 - **forestland**
 - **rangeland field test sites and**
 - **design carbon portfolios in conjunction with industry, tribal members, and landowners**
 - **Design plans for cropland and rangeland field test sites have been submitted**

BSCSP Terrestrial Sequestration Activities

- Carbon Markets
 - Market-based storage and verification protocols
 - Design carbon portfolios in conjunction with industry, tribal members, and landowners
- Terrestrial Pilots
 - Agriculture
 - Forestland
 - Rangeland



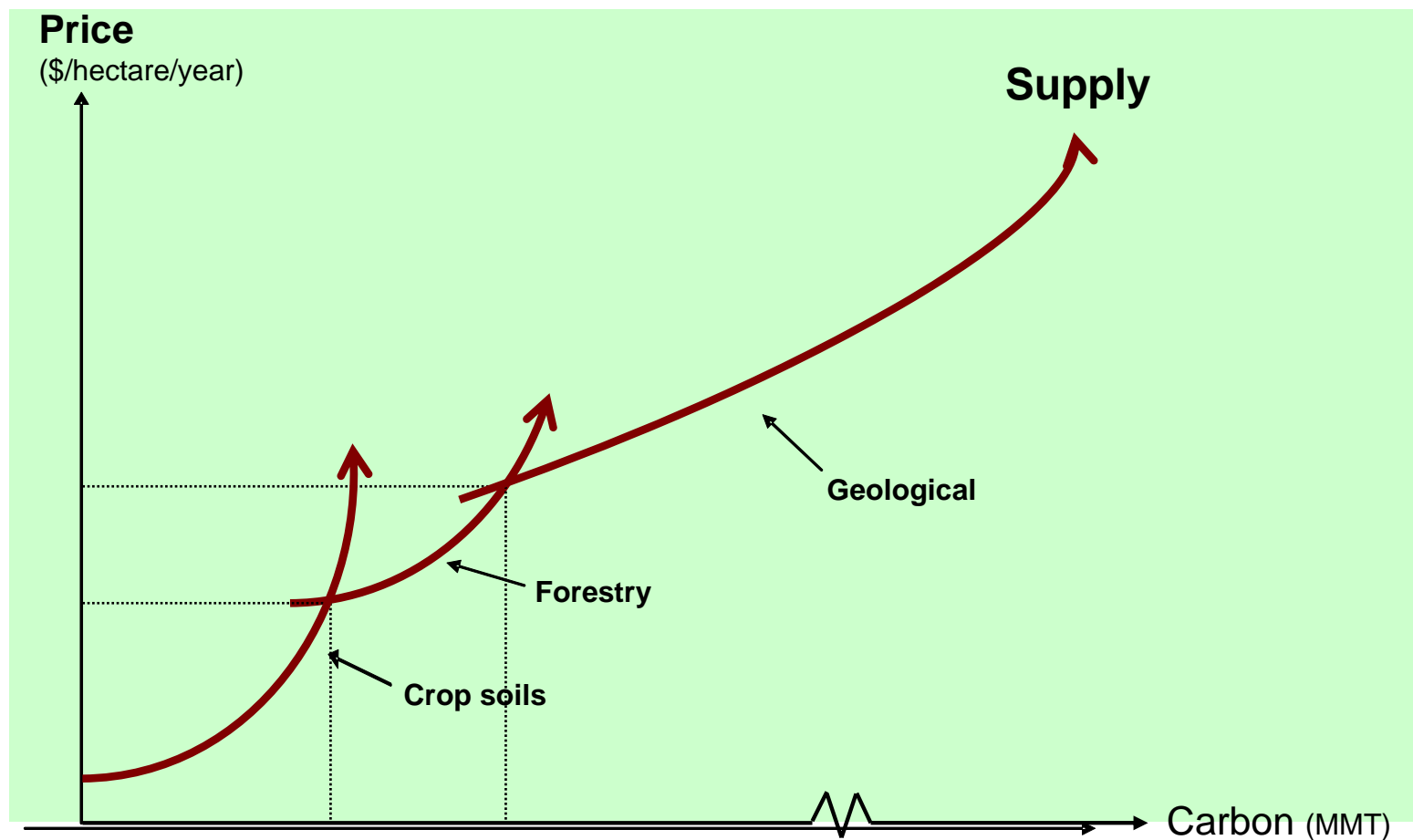
Carbon Market Efforts

- Implement pilot forestry, agroforestry, and cropland carbon sequestration projects in conjunction with landowners, and national and international carbon trading companies
- All pilot projects will be marketed through Nat Source via CCX and/or other emerging markets
- Two 12,500 ton portfolios (tribal & private landowners)
- Seating a Technical Standards Committee for the purpose of setting project standards for the portfolio projects

Components of an Economic/Risk Assessment Framework

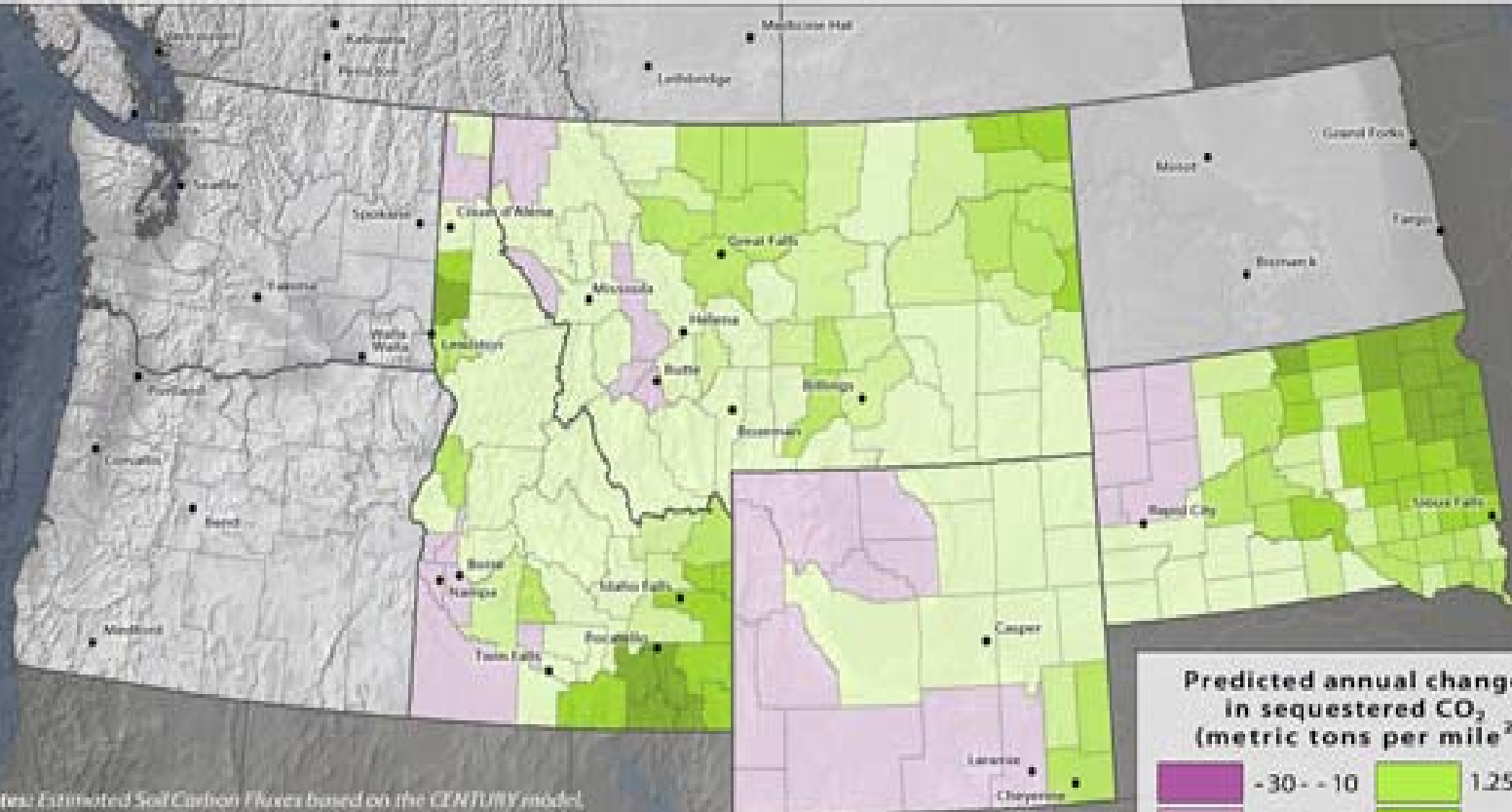
- Economic input on cost (from private sector)
- Legal and regulatory issues
- Monitoring, Measurement and Verification
- Common units for comparison – spatial, temporal metrics
- End product – regional supply curve(s) for Carbon

Regional Carbon Supply Curve

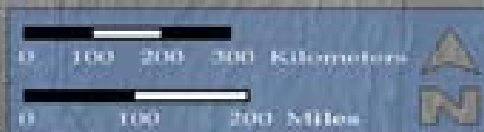


THE BIG SKY REGION: AGRICULTURAL SINK MODELING

CHANGE IN ESTIMATED SOIL CARBON FLUXES, BY COUNTY, UNDER SCENARIO 3*



Notes: Estimated Soil Carbon Fluxes based on the CENTURY model.
 NREL-CSU Modeling restricted to MT, WY, SD, and NE.
 Data sources: 2006 NCCDC; 2005 NRCS; 2006, 1997 USDA; 2005 CTC.



* Scenario 3: 25% increase in area under Conservation Reserve Program, at expense of areas of conventional tillage.

Predicted annual change
 in sequestered CO₂
 (metric tons per mile²)



Phase II Regulatory Compliance and Public Outreach

- **Regulatory and Public Involvement Action Plan (currently under revision)**
- **Regulatory Permitting Guidelines**
- **Energy Future Coalition**
- **Annual Energy Forum & Report**
- **State Legislative Symposia**
- **Partnership Recognition/Media Network**
- **National Outreach Working Group**
- **Capacity Building**

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